Using Multibeam Echosounder Backscatter To Characterize Seafloor Features

Geocoder Processing Gives Multibeam Echosounder Backscatter an Advantage Over Side Scan Sonar in Producing Reliable Seafloor Maps

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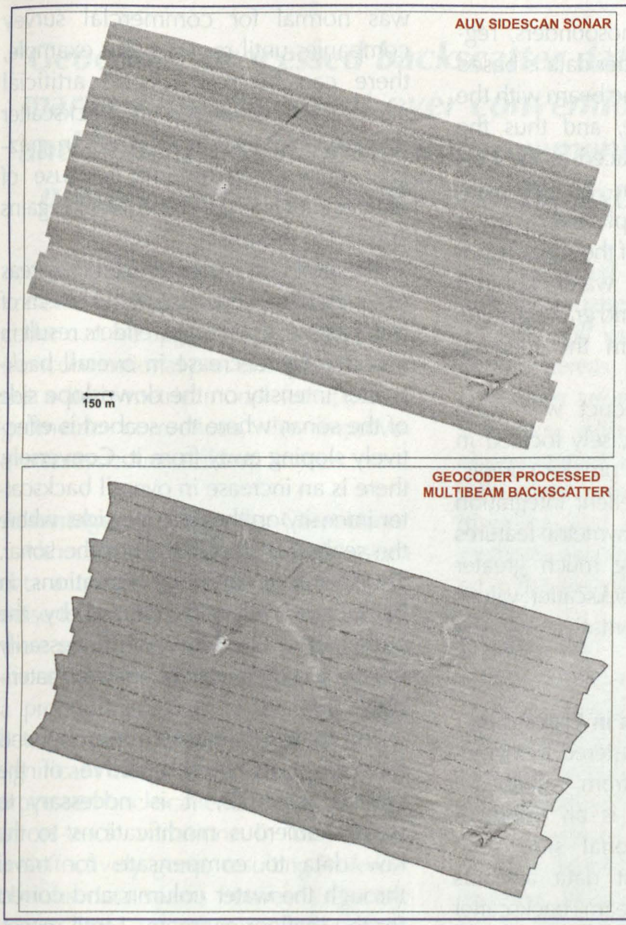
Both multibeam echosounders and side scan sonars can be used to collect acoustic backscatter data, the data obtained from the reflection of acoustic energy back toward a sonar device, where its intensity can be measured. After various corrections are applied to the data, backscatter intensity is essentially a function of the seafloor's physical properties, namely acoustic impedance, roughness (grain-size and small-scale topography) and volume inhomogeneity (variability in the thin layer of sediment penetrated by the acoustic signal).

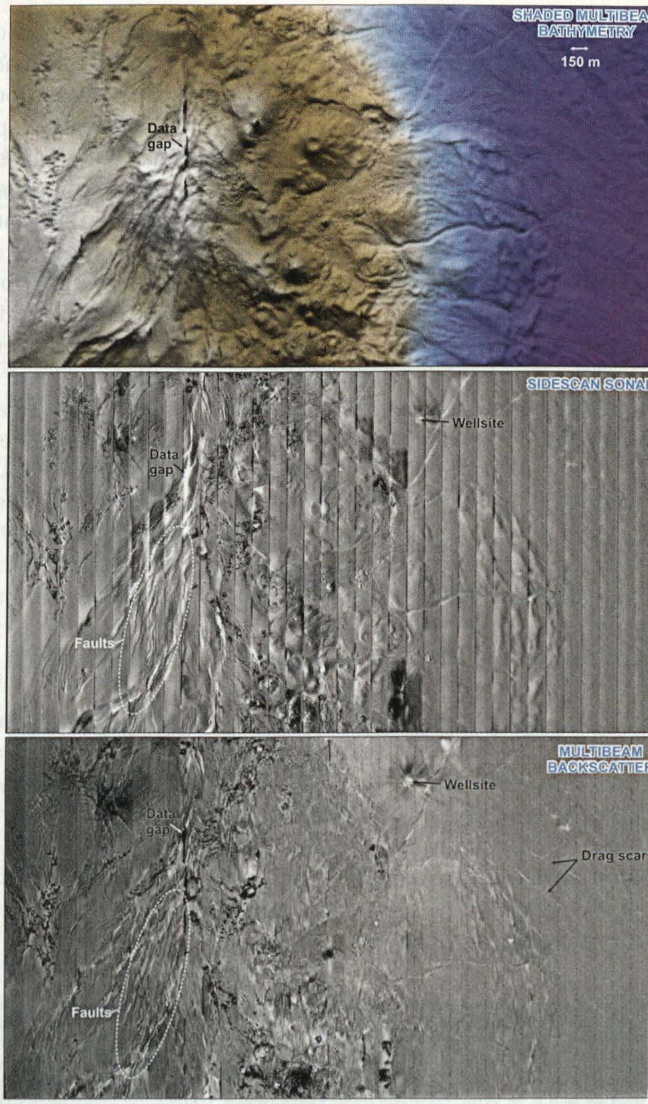
The use of backscatter data from side scan sonars has been widespread across many disciplines since it was developed in the 1950s, but multibeam echosounder backscatter has been finding an increasing base of users. For many years now, fisheries investigators have been utilizing multibeam echosounder backscatter data for habitat mapping, and hydrographers have been using it for target detection in shallow water.

However, it is only in recent years that multibeam echosounder backscat-

Positioning errors in surface towed side scan can result in features being misplaced by as much as 30 meters. Artificial across-track variation in backscatter intensity, bottom-tracking errors and acoustic shadows, highlighted in these images, can hinder seafloor characterization efforts.



(Above) Side scan mosaic (top) and Geocoder-processed multibeam backscatter (bottom) from the same AUV survey. Some features in the multibeam data are not visible in the side scan.



(Above, right) Shaded bathymetry (top), side scan mosaic (middle) and Geocoder-processed multibeam backscatter (bottom) from the same AUV survey over very rough terrain.

ter has come into common use in deepwater site investigations for oilfield developments.

Recent developments in multibeam echosounder backscatter processing, specifically an integrated suite of processing algorithms called Geocoder (developed by Luciano Fonseca and Brian Calder of the University of New Hampshire), are now included in most commercially available processing software. These tools allow end users to produce properly corrected backscatter mosaics and add more robust qualitative and quantitative discrimination of seabed materials to their seafloor characterizations. Fully corrected backscatter data increases confidence in interpretations of seabed features, and it offers an improved baseline dataset for implementing automated mapping techniques, which can potentially produce more detailed maps in less time. The corrected backscatter data is also more appropriate for integration with sediment samples and subsequent quantitative analysis. These mapping efforts are of benefit to engineering favorability assessments and other types of seafloor investigations.

Multibeam and Side Scan Sonars

Side scan sonars and multibeam echosounders both collect acoustic backscatter that can be interpreted to represent variations in seabed materials. Side scan sonar systems are specifically designed for this purpose, whereas most multibeam echosounder systems that are presently in operation in connection with oil industry activities were designed to collect very accurate bathymetry, with backscatter data being a byproduct of the soundings.

Conventional side scan sonar systems (excluding more sophisticated systems, such as those that use interferometry, beam forming and synthetic aperture technology) do not measure water depth, but the images contain indirect bathymetric information in the form of an increase in backscatter when the seafloor slopes toward the sonar and a decrease in backscatter when the seafloor slopes away from it. The result is "acoustic shadows" behind features with relief relative to their surroundings.

So, in brief summation, both side scan and multibeam backscatter data can be used to detect seafloor anomalies. However, backscatter data from multibeam echosounders can have advantages over conventional side scan data that arise from the careful way in which transmit/receive beams are traced to a precise location on the seafloor. First, with multibeam echosounders, bathymetry and backscatter data are collected simultaneously, and so bathymetry and backscatter are precisely coregistered (recorded at the same time and position) in 3D space. Second, since the area of insonfication (the footprint) is known precisely, raw multibeam backscatter can be radiometrically corrected for its travel path and geometrically corrected for the shape of the seafloor in the area of insonfication.

Effects of Seafloor Topography

With conventional side scan sonars, particularly those towed behind a surface vessel, there can be large positioning errors that result in mismatches in the location of seafloor features between adjacent survey lines, depending on the effort expended in positioning.

Although co-location can be greatly improved on an autonomous underwater vehicle (AUV) platform, where the navigation is more precise and multibeam and side scan transducers are very close to each other, there can still be issues over rough and/or steeply dipping terrain. These issues arise from the different methods of mapping backscatter data onto the seafloor. Conventional side scan processing typically assumes a flat seafloor and so is not bathymetrically corrected. This can result in a noticeable misplacement of seabed features and pronounced acoustic shadows behind features with relief, and thus lead to ambiguity in the backscatter data from the features.

With multibeam echosounders, registration of the backscatter data is based on the intersection of the beam with the digital seafloor profile, and thus the backscatter value is placed at the correct depth, even on an irregular seafloor. This is accomplished by using the recorded motions of the sonar head, along with applying water column refraction corrections and grazing angle corrections taken from the cleaned bathymetry model.

The final data product will yield backscatter values precisely located in three dimensions. This precise coregistration allows for excellent integration of backscatter with bathymetric features in the data, providing much greater confidence that the backscatter values are actually representative of the seafloor features.

Recent Developments in Processing

The precisely coregistered bathymetry and backscatter from multibeam echosounder systems is an improvement over conventional side scan sonar, but significant data artifacts remain if the multibeam backscatter processing stops at this stage, which was normal for commercial survey companies until recently. For example, there can be pronounced artificial across-track variations in backscatter intensity that arise from errors in grazing angle compensation because of deficiencies in the time-varied gains applied in processing.

The problem is exacerbated in areas of rough terrain because of the effects of a sloping seafloor. Slope effects result in a noticeable decrease in overall backscatter intensity on the downslope side of the sonar, where the seabed is effectively sloping away from it. Conversely, there is an increase in overall backscatter intensity on the upslope side, where the seabed is sloped toward the sonar. The result is artificial variations in backscatter intensity caused by the bathymetry that are not necessarily related to differences in seabed materials.

To obtain backscatter measurements that are truly representative of the seabed materials, it is necessary to make numerous modifications to the raw data to compensate for travel through the water column and correct for the seafloor geometry. Until recently, the backscatter data collected by commercial survey companies was not processed to its fullest advantage because of the limitations of the processing software.

It was not until the development of the Geocoder algorithms and their inclusion in various commercially available software packages that properly corrected backscatter data could be readily obtained.

Geocoder uses the original acquisition data, considers any modifications made to it, and then applies various radiometric and geometric corrections. Each raw backscatter sample is corrected for the time-varied gains, transmit powers and receiver gains that are applied during acquisition. Then the processing considers the transmit/receive beam pattern and compensates for spherical spreading, attenuation in the water column, seafloor slope and the actual area of insonification on the seafloor.

In addition, the processing applies a speckle-noise reduction algorithm. With this suite of corrections applied, the resulting backscatter dataset is more representative of the actual relative variations in seabed materials and, thus, represents a marked improvement over

"Geocoder-processed backscatter data represents a marked improvement over conventional side scan and is also a significant improvement over incompletely corrected multibeam backscatter data."

conventional side scan or incompletely corrected multibeam backscatter. Geocoder can be applied to side scan data (nonconventional processing), but without a bathymetric model for applying geometric corrections, the improvements are not as striking.

Advantages of Geocoder Correction

Although the conventional side scan data acquired by stable and relatively noise-free AUV platforms is very good, there are still artificial across-track variations in side scan backscatter intensity, a pronounced nadir zone (the seam between port and starboard beams) and significant image speckle. In Geocoder-processed backscatter data, the artificial across-track variations in backscatter are effectively gone, resulting in fewer obvious data seams between adjacent survey lines, a narrower nadir zone and reduced speckle noise. Thus, the imagery has an overall more uniform tone against which seafloor features are better defined, and sometimes subtle features are revealed that are absent in side scan imagery.

Geocoder-processed backscatter data clearly represents a marked improvement over conventional side scan and is also a significant improvement over incompletely corrected multibeam backscatter data.

Over very rough bathymetry, artificial across-track variations in backscatter data, slope effects and acoustic shadows are often rampant in side scan data, but are greatly reduced in the multibeam echosounder data. This is possible with multibeam systems because the acoustic shadow zone that is cast on one side of a feature can be partially or completely filled in with data acquired from an adjacent survey line on the other side of the feature.

Conversely, in generating conventional side scan mosaics, one line is typically placed over or under portions of an adjacent line, so shadow zones are not filled in. These shadow zones are problematic for automated mapping methods using conventional side scan mosaics, as they need to be manually excluded. Survey coverage holes over the roughest terrain are represented with null values in the backscatter data, whereas in side scan mosaics, data holes are represented by acoustic shadows. Although data gaps are always undesirable, retaining them as null values is beneficial for automated mapping and seafloor classification methods, as they can be easily excluded in the analysis.

Conclusions

Fully corrected backscatter data from multibeam echosounder systems can significantly improve the accuracy of, and confidence in, interpretations of seabed features and materials. Furthermore, corrected backscatter data is a superior baseline dataset for implementing automated mapping techniques. Backscatter values can be contoured to form feature polygons, and the values can also be mathematically manipulated and merged with other datasets, which is a useful technique in creating maps for site favorability assessments. The result is a more reliable and potentially a much more detailed map that can be created in less time. The corrected backscatter data is also more appropriate for integration with sediment samples and subsequent quantitative discrimination.

Acknowledgments

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